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PROPERTIES OF F-34 (JP-8) FUEL FOR 1988

Charles R. Martel
Fuels Branch
Fuels and Lubrication Division

April 1989

Summary Report for Period January 1988 - December 1988

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WRIGHT RESEARCH AND DEVELOPMENT CENTER
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This report summarizes the properties of 95 F-34 fuels delivered to U.S. military installations during calendar year 1988. Most of the fuel was obtained from refineries in Germany, Spain, Sicily and Greece, with one shipment obtained from Bahrain and seven shipments from Venezuela. F-34 destinations included the Central European Pipeline (via terminals in Germany and France), the United Kingdom Pipeline, the Azores, Spain, Italy, Korea and the United States.

All of the F-34 fuels met Specification MIL-T-83133B requirements except for Particulate Matter (5 of the 95 fuels slightly exceeded the limit). Most fuel properties were well within specification limits. Two controversial specification limits are the 0.002 weight percent limit on mercaptan sulfur (commercial jet fuel specifications allow up to 0.003 weight percent) and the filtration-time limit. None of the fuels exceeded 0.001 weight percent mercaptan sulfur. Also, all fuels met the filtration time limit, although several fuels were at the specification limit of 15 minutes.

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FOREWORD

NATO Europe, including all USAF bases in Europe, converted from NATO F-40 (JP-4) fuel to NATO F-34 (JP-8) fuel during calendar year 1988. Previously, only the USAF bases in the United Kingdom have used F-34 (since 1979).

This report documents the properties and sources of F-34 delivered to US forces in Europe during calender year 1988. These data were obtained from the fuel test reports, which are submitted by the suppliers with each batch of fuel procured by the US Defense Fuels Supply Center (DFSC). The DFSC, in turn, delivers fuel to US Air Force Bases and other users.

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SECTION 1 - INTRODUCTION

The USAF is in the process of converting to NATO F-34 (JP-8) as its primary combat fuel. In 1979, USAF operations within the United Kingdom were converted from JP-4 (NATO F-40) to F-34. During 1988, USAF and NATO operations in Europe were also converted to F-34. USAF operations in the Pacific (Japan, Korea, and Okinawa) are scheduled to be converted to F-34 by 1991. The USAF conversion to F-34 within the continental US (CONUS) is being considered.

F-34 (JP-8) is commercial Jet A-1 (NATO F-35) with fuel system icing inhibitor, corrosion inhibitor/lubricity improver additive, and static dissipater additive. Unlike CONUS Jet A commercial jet fuel, European Jet A-1 (NATO F-35) is required to contain a static dissipater additive and may contain a corrosion inhibitor /lubricity improver additive. Although not used within the CONUS, Jet A-1 is the primary commercial jet fuel for Europe and many other parts of the free world. In NATO, much of the F-34 is being procured and shipped as F-35. At or near its destination, the additives required to convert F-35 to F-34 are injected into the fuel.

The primary commercial jet fuel within the CONUS is Jet A (no NATO designation). Jet A is very similar to F-35 but has a higher freeze point. The higher freeze point of Jet A allows the producers to include higher boiling fractions, resulting in a fuel that is slightly more dense and has a slightly higher distillation range than F-35[1].

Jet A, F-34 and F-35 are kerosene fuels having a minimum flash point of 38°C (100°F). The standard USAF jet fuel from the middle 1950s until 1988 was JP-4 (F-40). F-40 is a wide cut fuel, consisting of about 60 percent naphtha (gasoline) and 40 percent kerosene. The naphtha causes F-40 to be quite volatile, resulting in a flash point of about -23 to -12°C (-10° to +10°F). JP-5 (NATO F-44) is the Navy's primary jet fuel. With a minimum flash point of 60°C (140°F), it is the least volatile of military and commercial jet fuels.

F-34 was developed in the late 1960s to decrease the incidence of combat-initiated aircraft fires. During the Vietnam war, similar combat flight operations flown by the Navy, which used F-44, were compared to those by the Marines and Air Force, which used F-40.

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1 Martel, Charles R., Properties of JP-8 Jet Fuel, AFWAL-TR-88-2040, May 1988.

The Navy had lower loss rates as a result of fewer gunfire-initiated fires and explosions, as compared to the Air Force and Marines. Subsequent gunfire tests confirmed that fuel volatility significantly affects the chances of and severity of in-flight aircraft fires. Also, analyses of impact-survivable crashes showed that fuel volatility also affects the chances for post-crash fires and increased fatalities. These data indicate that a kerosene-based fuel will reduce combat aircraft losses and crash fatalities as compared to F-40.

The properties of F-34 were chosen to give: (a) low volatility, as measured by flash point, (b) low freezing point, needed for world-wide operations of USAF aircraft, (c) high availability in wartime and low cost in peacetime, and (d) compatibility with existing aircraft. Commercial Jet A-1 (F-35) fuel adequately met these requirements. In addition, selection of an existing standard jet fuel would simplify logistics in peacetime and increase availability in time of war. Thus, the bulk properties of F-34 were selected to be identical to those of Jet A-1.

The properties of F-34 procured from 1984 through early 1988 were previously reported[1]. F-34 property data are needed by aircraft designers and operators to estimate aircraft and engine performance. This report documents the properties of F-34 and F-35 fuels procured for use by the USAF in Europe during 1988. Fuel sources included Bahrain, Germany, Greece, Sicily, Spain, and Venezuela.

SECTION II - DATA AND DATA ANALYSIS

1. Data Source

The data for this report were obtained from suppliers' test reports, required for each batch of fuel procured by the Defense Fuels Supply Center (DFSC). (The DFSC procures all F-34 fuel for the US Department of Defense.)

Table 1 lists the sources of each fuel batch, the date, and most of the specification properties reported. Table 2 lists the quantities shipped and their destination.

2. Data Analysis

Table I, which lists the data reported for each fuel batch, also lists a simple statistical average of each property for each fuel source. Also, the hydrogen content (percent by weight) was calculated using ASTM D3343, as this was not listed in all test reports. In addition to the reported heat of combustion, which included calorimetric measurements and conversions based on aniline-gravity correlations, the heat of combustion was calculated using ASTM D 3338. This provides a single standard of reference for the heat of combustion.

Specification MIL-T-83133 for F-34 requires the mercaptan sulfur to be measured or requires the use of the Doctor test (a pass/fail test.) Thus, where "NEG" is reported in Table 1, the fuel successfully passed the Doctor test. A "Negative" Doctor test implies that the mercaptan sulfur content is below 0.001 weight percent.

The additives injected into the fuel are shown in Table 1, as reported on the fuel test report form for each batch. These data were not always complete, as the amount of an antioxidant or corrosion inhibitor was reported, but the type or trade name of the additive was not given.

For NATO F-34, only four corrosion inhibitor additives are approved by the NATO guide specification[2]. As seen in Table 1, only Ethyl Corporation's Hitec 580 and Nalco Chemical Company's

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2 STANAG 3747 F&L - Guide Specifications (Minimum Quality Standards) For Aviation Turbine Fuels (F-34, F-35, F-40, and F-44)

TABLE 1. PROPERTIES OF F-34 FUELS FOR 1988

I.D. NO.	SOURCE	DATE YR-MO	ACID NO	AROM %	OLEF %	TOTAL SULFUR	MERCAP SULFUR	D86 DISTILLATION (C) IBP	%10	%20	%50	%90	EP	MEAN	FLASH PT	GRAV API	FREEZ POINT	VISC CST
114	GE, GELSENKIRCHEN	8807	0.004	13.5	0.3	0.01	0.0010	182	192	197	206	229	242	209	60	42.2	-60.0	5.0
111	GE, GELSENKIRCHEN	8807	0.003	11.0	0.3	0.01	0.0010	179	191	194	204	227	240	207	58	43.2	-60.0	4.9
155	GE, GELSENKIRCHEN	8807						181	190	194	203	228	240	207	60	43.4	-61.0	
123	GE, GELSENKIRCHEN	8808	0.003	13.8	0.3	0.01	0.0010	174	186	189	199	223	235	203	57	42.8	-60.0	4.6
124	GE, GELSENKIRCHEN	8808	0.003	12.8	0.3	0.01	0.0010	165	179	182	193	218	232	197	55	43.2	-60.0	4.4
122	GE, GELSENKIRCHEN	8808	0.003	13.7	0.3	0.01	0.0010	176	189	191	201	223	235	204	59	42.6	-60.0	4.9
121	GE, GELSENKIRCHEN	8808	0.004	12.9	0.1	0.01	0.0010	185	194	197	206	228	241	209	61	42.4	-60.0	5.1
125	GE, GELSENKIRCHEN	8808	0.005	13.4	0.3	0.01	0.0010	171	183	186	198	224	237	202	57	43.2	-60.0	4.5
153	GE, GELSENKIRCHEN	8809	0.008	13.3	0.3	0.01	0.0010	166	181	184	197	227	249	202	51	43.4	-60.0	4.4
154	GE, GELSENKIRCHEN	8809	0.003	12.7		0.01	0.0010	173	183	186	198	226	242	202	54	43.3	-60.0	4.5
132	GE, GELSENKIRCHEN	8809	0.004	12.0	0.3	0.01	0.0010	171	182	186	198	225	239	202	57	43.6	-60.0	4.5
135	GE, GELSENKIRCHEN	8809	0.004	12.5	0.3	0.01	0.0010	168	181	186	197	227	242	202	55	44.3	-60.0	4.4
150	GE, GELSENKIRCHEN	8809	0.004	13.9	0.3	0.01	0.0010	165	181	184	196	225	244	201	50	43.1	-30.0	4.4
136	GE, GELSENKIRCHEN	8809	0.004	11.1	0.3	0.01	0.0010	172	182	185	197	225	239	201	56	43.8	-60.0	4.3
133	GE, GELSENKIRCHEN	8809	0.003	12.7	0.3	0.01	0.0010	174	184	186	198	225	238	202	58	43.4	-60.0	4.5
152	GE, GELSENKIRCHEN	8810	0.003	13.4	0.3	0.01	0.0010	170	182	185	198	226	247	202	51	43.2	-60.0	4.4
161	GE, GELSENKIRCHEN	8810	0.004	13.1	0.3	0.01	0.0010	164	179	182	196	227	242	201	48	43.4	-60.0	4.3
160	GE, GELSENKIRCHEN	8810	0.004	13.3	0.3	0.01	0.0010	165	182	185	197	226	243	202	52	43.2	-60.0	4.4
156	GE, GELSENKIRCHEN	8810	0.004	12.9	0.3	0.01	0.0010	169	182	186	199	227	242	203	52	43.2	-60.0	4.5
174	GE, GELSENKIRCHEN	8811	0.003	13.8	0.3	0.01	0.0010	162	179	182	195	224	240	199	49	43.2	-60.0	4.3
162	GE, GELSENKIRCHEN	8811	0.004	13.2	0.3	0.01	0.0010	166	179	184	197	227	244	201	49	43.4	-60.0	3.7
173	GE, GELSENKIRCHEN	8811	0.004	13.9	0.3	0.01	0.0010	164	179	184	197	227	241	201	50	43.2	-60.0	4.3
176	GE, GELSENKIRCHEN	8811						165	179	182	195	226	242	200	51	43.3	-60.0	
177	GE, GELSENKIRCHEN	8811	0.003	13.4	0.3	0.01	0.0010	161	176	180	193	224	241	198	50	43.5	-60.0	4.3
182	GE, GELSENKIRCHEN	8811	0.003	13.2	0.3	0.01	0.0010	168	181	185	199	229	243	203	51	43.3	-60.0	4.3
178	GE, GELSENKIRCHEN	8812	0.004	13.4	0.3	0.01	0.0010	167	180	186	198	228	245	202	51	43.5	-60.0	4.3
187	GE, GELSENKIRCHEN	8812						165	178	183	196	228	247	201	51	43.7	-60.0	
188	GE, GELSENKIRCHEN	8812	0.002	13.9	0.3	0.01	0.0010	163	178	183	196	228	246	201	49	43.4	-55.0	4.3
189	GE, GELSENKIRCHEN	8812	0.003	13.8	0.3	0.01	0.0010	168	180	184	197	228	246	202	49	43.4	-60.0	4.2
	GELSENKIRCHEN, AVG.		0.004	13.1	0.3	0.01	0.0010	170	182	185	198	226	242	202	53.5	43.3	-60	4.5
72	GE, KARLSRUHE	8804	0.010	16.5	0.6	0.02	0.0002	152	173	181	197	220	240	197	44	46.2	-54	3.9
82	GE, KARLSRUHE	8804	0.007	15.4	0.7	0.09	0.0008	152	173	180	196	226	244	198	44	46.9	-53	3.9
106	GE, KARLSRUHE	8806	0.003	16.7	0.6	0.06	0.0005	156	175	183	198	226	243	200	48	46.0	-52.0	4.0
107	GE, KARLSRUHE	8806	0.003	16.5	0.6	0.04	0.0004	154	174	184	201	231	245	202	48	45.8	-51.0	4.2
	KARLSRUHE, AVE		0.006	16.3	0.6	0.05	0.0005	154	174	182	198	226	243	[illegible]	46.0	46.2	-52.5	4.0
109	GE, WORTH	8807	0.010	17.8	0.5	0.01	0.0009	151	163	167	179	217	245	186	45	44.8	-60.0	3.4
139	GE, WORTH	8808	0.010	18.6	0.1	0.02	0.0001	162	168	171	179	215	247	187	51	45.2	-60.0	3.2
138	GE, WORTH	8808	0.010	17.0	0.4	0.01	0.0001	156	168	170	177	213	245	186	48	44.9	-60.0	3.2
140	GE, WORTH	8809	0.010	17.4	0.9	0.01	0.0001	158	167	169	178	212	243	186	45	46.1	-65.0	3.3
113	GE, WORTH	8807	0.010	16.4	0.4	0.01	NEG	154	166	167	181	218	245	188	47	44.4	-60.0	3.5
112	GE, WORTH	8807	0.010	17.2	1.0	0.01	NEG	149	162	167	179	220	249	187	41	44.8	-60.0	3.4
115	GE, WORTH	8807	0.010	16.4	0.4	0.01	[illegible]	157	172	175	187	221	249	193	51	44.0	-60.0	3.5
127	GE, WORTH	8808	0.010	18.6	0.1	0.02	0.0001	162	168	177	179	215	247	187	51	45.1	-60.0	3.2
120	GE, WORTH	8808	0.010	17.2	0.5	0.01	0.0001	162	173	174	186	222	251	194	52	44.1	-58.0	3.9
126	GE, WORTH	8808	0.010	17.0	0.4	0.01	0.0001	156	168	[illegible]	177	213	245	184	48	44.9	-60.0	3.2
159	GE, WORTH	8809	0.010	17.6	1.0	0.00	0.0001	151	163	166	175	210	253	183	46	[illegible]	-60.0	3.2
149	GE, WORTH	8809	0.010	17.9	0.8	0.01	0.0001	150	162	167	179	221	248	187	45	44.7	-60.0	3.2
167	GE, WORTH	8810	0.010	17.6	0.3	0.01	0.0001	155	166	177	182	228	255	192	49	44.9	-58.0	3.4
151	GE, WORTH	8810	0.010	17.5	0.7	0.01	0.0001	140	162	166	179	226	254	189	43	44.3	-60.0	3.2
164	GE, WORTH	8810	0.010	17.5	0.7	0.01	0.0001	148	162	166	179	226	254	189	43	44.3	-60.0	3.2
166	GE, WORTH	8810	0.010	17.6	0.3	0.01	0.0001	155	166	177	182	228	255	192	49	[illegible]	-58.0	3.4
165	GE, WORTH	8810	0.010	18.2	0.2	0.01	0.0001	155	167	177	184	229	256	193	45	44.1	-55.0	3.7
157	GE, WORTH	8810	0.010	16.8	0.3	0.01	0.0001	152	165	169	183	222	257	192	47	44.1	-59.0	3.6
168	GE, WORTH	8811	0.010	18.0	0.1	0.01	0.0001	152	164	168	179	224	256	189	52	44.4	-60.0	3.4
183	GE, WORTH	8812	0.010	18.6	0.4	0.02	0.0001	154	166	169	181	222	257	190	48	45.2	-60.0	3.7
184	GE, WORTH	9312	0.010	18.1	0.7	0.01	0.0001	152	163	166	177	219	253	186	49	44.7	-60.0	3.4
185	GE, WORTH	8812	0.010	16.5	0.4	0.01	0.0001	154	164	168	180	222	253	189	47	44.8	-60.0	3.6
	GE, WORTH AVERAGES		0.010	17.5	0.5	0.01	0.0001	154	166	170	180	220	251	189	47.1	44.7	-59.8	3.4

EEZ INT	VISC CST	SMOKE PT	H2 WT %	COMB REPORT	(BTU/LB) D3338	EXIST GUM	WSIM	FSII %	ANTIOXIDANT CONC	ANTIOXIDANT TYPE	CORROS INHIB MG/L	CORROS INHIB TYPE	MDA MG/L	FILT TIME	SOLIDS MG/L	JFTOT MM	JFTOT CODE	CETANE INDEX
0.0	5.0	24.0	13.77		18577	0.4	94		20.0		14.8			12	0.2	1	1	41.0
0.0	4.9	25.0	13.92	18612	18612	0.3	98		20.0		13.4			13	0.8	2	1	42.0
1.0			14.30		18691	1.6									0.3			
0.0	4.6	24.0	13.60		18576	0.3	96		20.0		13.8			15	1.3	1	1	39.0
0.0	4.4	25.0	14.03		18581	0.5	96		20.0		13.3			6	0.4	0	1	39.0
0.0	4.9	24.0	14.02		18576	0.3	95		20.0		15.3			12	1.6	3	1	40.0
0.0	5.1	25.0	14.05		18586	0.2	94	0.13	20.0		14.0			13	0.8	3	1	41.0
0.0	4.5	25.0	14.07		18586	0.3	91		20.0	MTBX55	14.2	HI 580		13	0.3	1	1	40.0
0.0	4.4	25.0	14.08	18486	18591	0.3	98		20.0		15.8			13	0.5	1	1	40.0
0.0	4.5	24.0	14.08	18486	18594	0.3	98		20.0		15.2			12	1.1	0	1	39.0
0.0	4.5	25.0	14.12	18529	18604	0.2	97		20.0		16.2			12	0.3	2	1	41.0
0.0	4.4	25.0	14.17	18523	18616	0.2	98		20.0		13.5			11	0.7	1	1	39.0
0.0	4.4	24.0	14.04	18615	18578	0.2	96		20.0		16.8			14	0.1	0	1	39.0
0.0	4.3	25.0	13.66	18486	18614	0.3	98		20.0		15.6			11	1.0	1	1	40.0
0.0	4.5	25.0	14.10	18529	18596	0.3	97		20.0		13.7			11	0.7	1	1	40.0
0.0	4.4	24.0	14.08	18486	18586	0.4	100		20.0		15.3			12	0.9	0	1	40.0
0.0	4.3	24.0	14.06	18529	18590	0.2	97		20.0		13.9			13	0.8	1	1	38.0
0.0	4.4	24.0	14.10	18529	18587	0.3	100		20.0		13.2			13	0.6	0	1	38.0
0.0	4.5	24.0	14.08	18529	18591	0.2	100		20.0		14.7			13	0.4	0	1	39.0
0.0	4.3	24.0	14.04	18572	18579	0.3	100		20.6		14.4			12	0.5	0	1	38.0
0.0	3.7	24.0	14.08	18486	18590	0.1	97		20.0		13.4			14	1.9	1	1	39.0
0.0	4.3	24.0	14.05	18572	18581	0.3	100		20.0		13.7			12	0.5	0	1	39.0
0.0					18679	0.6								11	0.9			
0.0	4.3	24.0	14.06	18572	18585	0.4	98		20.0		12.7			12	0.7	0	1	39.0
0.0	4.3	24.0	14.08	18572	18592	0.2	100		20.0		12.9			14	0.8	0	1	38.0
0.0	4.3	24.0	14.09	18572	18593	0.2	98		20.0		8.8			13	0.6	1	1	39.0
0.0			14.30		18689									13	0.4			
5.0	4.3	24.0	14.06	18572	18585	0.3	99		20.0		13.6			11	0.6	1	1	38.0
0.0	4.2	24.0	14.07	18572	18587	0.3	100		20.0		13.2			10	0.6	1	1	38.0
)	4.5	24.3	14.04	18541	18600	0.3	98		20.0		14.1			12.2	0.70	0.8	1.0	39.3
.	3.9	24	14.01	18628	18617	1.0	98	0.13	22.4		20.2			7	0.4	0	1	45.0
5	3.9	25	14.09	18637	18634	1.0	97	0.15	22.4		20.2			6	0.1	0	0	45.0
2.0	4.0	24.0	13.89	18625	18612	0.5	97	0.14	21.7		20.2			6	0.2	0	0	45.0
.0	4.2	23.0	13.90	18612	18618	0.5	98	0.13	21.8		17.8			7	0.3	0	1	44.0
2.5	4.0	24.0	13.97	18626	18620	0.8	98	0.14	22.1		19.6			6.5	0.25	0.0	0.5	44.8
.0	3.4	25.0	13.67	18572	18557	1.0	85	0.15	18.0	KERO TP	20.0	HI 580		5	0.8	0	0	33.0
.0	3.2	25.0	14.11	18615	18560	1.0	89	0.15	18.0	KERO TP	20.0	HI 580		6	0.9	0	0	34.0
.0	3.2	25.0	14.05	18615	18565	1.0	92	0.15	18.0	KERO TP	20.0	HI 580		6	0.2	0	0	34.0
.0	3.3	25.0	14.14	18615	18566	1.0	91	0.15	18.0	KERO TP	20.0	HI 580		6	0.8	0	0	35.0
.0	3.5	25.0	13.70	18572	18564	1.0	85	0.14	18.0	KERO TP	21.0	HI 580		5	0.2	0	0	34.0
.0	3.4	26.0	13.92	18552	18563	1.0	89	0.15	17.0	KERO TP	20.0	HI 580		5	0.2	0	0	33.0
.0	3.5	25.0	13.71	18615	18565	1.0	96	0.15	18.0	KERO TP	22.0	HI 550		6	0.5	0	0	36.0
.0	3.2	25.0	13.60	18615	18558	1.0	89	0.15	18.0	KERO TP	20.0	HI 580		6	0.9	0	0	34.0
.0	3.9	25.0	14.09	18572	18562	1.0	95	0.15	18.0	KERO TP	20.0	HI 580		6	0.7	0	0	36.0
.0	3.2	25.0	14.05	18615	18565	1.0	92	0.15	18.0	KERO TP	20.0	HI 580		6	0.2	0	0	34.0
.0	3.2	25.0	14.05	18572	18564	1.0	97	0.15	18.0	KERO TP	20.0	HI 580		6	0.7	0	0	33.0
.0	3.2	25.0	14.02	18572	18556	1.0	93	0.15	20.0	KERO TP	20.0	HI 580		6	0.3	0	0	33.0
.0	3.4	25.0	14.08	18615	18573	1.0	91	0.15	18.0	KERO TP	20.0	HI 580		6	0.5	0	0	35.0
.0	3.2	25.0	14.01	18572	18555	1.0	91	0.15	18.0	KERO TP	20.0	HI 580		8	0.8	0	0	33.0
.0	3.2	25.0	14.01	18572	18555	1.0	91	0.15	18.0	KERO TP	20.0	HI 580		8	0.8	0	0	33.0
.0	3.4	25.0	14.08	18615	18573	1.0	91	0.15	18.0	KERO TP	20.0	HI 580		6	0.5	0		35.0
.0	3.7	25.0	14.01	18572	18554	1.0	91	0.15	18.0	KERO TP	20.0	HI 580		7	0.8	0	0	35.0
.0	3.6	26.0	14.02	18572	18562	1.0	90	0.15	18.0	KERO TP	20.0	HI 580		8	1.0	0	0	34.0
.0	3.4	26.0	14.01	18572	18553	1.0	90	0.15	18.0	KERO TP	20.0	HI 580		6	0.8	0	0	40.0
.0	3.7	25.0	14.07	18615	18565	1.0	90	0.15	18.0	KERO TP	20.0	HI 580		6	0.0	0	0	35.0
.0	3.4	26.0	14.01	18572	18553	1.0	90	0.15	18.0	KERO TP	20.0	HI 580		6	0.5	0	0	32.0
.0	3.6	26.0	14.06	18572	18572	1.0	92	0.15	18.0	KERO TP	20.0	HI 580		8	0.4	0	0	34.0
.8	3.4	25.2	13.98	18580	18563	1.0	91	0.15	18.0		20.1			6.2	0.57	0.0	0.0	34.3

.T E	CORROS MG/L	INHIB TYPE	MDA MG/L	FILT TIME	SOLIDS MG/L	JFTOT MM	JFTOT CODE	CETANE INDEX	DIST AVE	D3338 UNCOR
	14.8			12	0.2	1	1	41.0	408.2	18578
	13.4			13	0.8	2	1	42.0	405.2	18614
					0.3				404.6	18691
	13.8			15	1.3	1	1	39.0	396.8	18578
	13.3			6	0.4	0	1	39.0	386.0	18582
	15.3			12	1.6	3	1	40.0	399.8	18577
	14.0			13	0.8	3	1	41.0	408.8	18587
'55	14.2	HI 580		13	0.3	1	1	40.0	395.0	18587
	15.8			13	0.5	1	1	40.0	395.0	18592
	15.2			12	1.1	0	1	39.0	396.2	18595
	16.2			12	0.3	2	1	41.0	395.0	18606
	13.5			11	0.7	1	1	39.0	395.0	18618
	16.8			14	0.1	0	1	39.0	393.2	18589
	15.6			11	1.0	1	1	40.0	394.4	18616
	13.7			11	0.7	1	1	40.0	396.2	18598
	15.3			12	0.9	0	1	40.0	395.6	18588
	13.9			13	0.8	1	1	38.0	393.2	18592
	13.2			13	0.6	0	1	38.0	395.0	18588
	14.7			13	0.4	0	1	39.0	396.8	18593
	14.4			12	0.5	0	1	38.0	390.8	18580
	13.4			14	1.9	1	1	39.0	393.8	18592
	13.7			12	0.5	0	1	39.0	393.8	18583
				11	0.9				392.0	18679
	12.7			12	0.7	0	1	39.0	387.8	18586
	12.9			14	0.8	0	1	38.0	397.4	18593
	3.8			13	0.6	1	1	39.0	395.6	18594
				13	0.4				393.2	18689
	13.6			11	0.6	1	1	38.0	393.2	18586
	13.2			10	0.6	1	1	38.0	395.0	18589
	14.1			12.2	0.70	0.8	1.0	39.3		
	20.2			7	0.4	0	1	45.0	386.0	18620
	20.2			6	0.1	0	0	45.0	389.0	18647
	20.2			6	0.2	0	0	45.0	391.4	18621
	17.8			7	0.3	0	1	44.0	395.6	18623
	19.6			6.5	0.25	0.0	0.5	44.8		
P	20.0	HI 580		5	0.8	0	0	33.0	367.4	18559
P	20.0	HI 580		6	0.9	0	0	34.0	369.2	18563
P	20.0	HI 580		6	0.2	0	0	34.0	366.8	18566
P	20.0	HI 580		6	0.8	0	0	35.0	366.2	18587
P	21.0	HI 580		5	0.2	0	0	34.0	371.0	18565
P	20.0	HI 580		5	0.2	0	0	33.0	368.6	18565
P	22.0	HI 580		6	0.5	0	0	36.0	380.0	18567
P	20.0	HI 580		6	0.9	0	0	34.0	369.2	18561
P	20.0	HI 580		6	0.7	0	0	36.0	382.6	18564
P	20.0	HI 580		6	0.2	0	0	34.0	366.8	18566
P	20.0	HI 580		6	0.7	0	0	33.0	362.8	18565
P	20.0	HI 580		6	0.3	0	0	33.0	369.2	18558
P	20.0	HI 580		6	0.5	0	0	35.0	377.6	18574
P	20.0	HI 580		8	0.8	0	0	33.0	372.2	18556
P	20.0	HI 580		8	0.8	0	0	33.0	372.2	18556
P	20.0	HI 580		6	0.5	0	-	35.0	377.6	18574
P	20.0	HI 580		7	0.8	0	0	35.0	380.0	18556
P	20.0	HI 580		8	1.0	0	0	34.0	377.6	18563
P	20.0	HI 580		6	0.8	0	0	40.0	372.2	18554
P	20.0	HI 580		6	0.0	0	0	35.0	373.4	18568
P	20.0	HI 580		6	0.5	0	0	32.0	367.4	18554
P	20.0	HI 580		8	0.4	0	0	34.0	371.6	18573
	20.1			6.2	0.57	0.0	0.0	34.3		

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TABLE 1. (CONTINUED)

I.D. NO.	SOURCE	DATE YR-MO	ACID NO	AROM %	OLEF %	TOTAL SULFUR	MERCAP SULFUR	D86 DISTILLATION (C) IBP	%10	%20	%50	%90	EP	MEAN	FLASH PT	GRAV API	FREEZ POINT
191	BAHRAIN	8812	0.001	19.2		0.14		149	166	172	191	232	250	196	40	48	-53
36	GREECE ST THEODORE	8801	0.005	16.5	0.6	0.11	0.0008	152	171	179	198	232	250	200	45	45.2	-50
27	GREECE ST THEODORE	8801	0.005	12.2	0.2	0.04	0.0008	147	170	178	193	226	253	196	43	46.3	-53
26	GREECE ST THEODORE	8802	0.004	16.0	0.3	0.05	0.0009	150	171	179	194	228	253	198	43	46.4	-52
25	GREECE ST THEODORE	8803	0.008	13.8	0.1	0.07	0.0008	154	172	179	190	213	245	192	47	47.4	-58
144	GREECE ST THEODORE	8804	0.006	15.1	0.3	0.06	0.0008	145	168	178	198	235	255	200	42	46.5	-47
130	GREECE ST THEODORE	8808	0.002	13.5	0.3	0.15	0.0008	144	171	179	199	236	253	202	43	45.8	-47
129	GREECE ST THEODORE	8808	0.002	13.5	0.3	0.15	0.0008	143	170	179	215	247	252	211	44	45.8	-48
171	GREECE ST THEODORE	8810	0.003	13.5	0.2	0.06	0.0010	148	169	177	190	223	248	194	41	46.8	-55
170	GREECE ST THEODORE	8810	0.005	12.2	0.1	0.01	0.0007	156	176	183	192	211	242	193	41	48.0	-58
	GREECE, AVERAGES		0.004	14.0	0.3	0.08	0.0008	148	170	179	196	227	250	198	43.2	46.5	-52
21	SICILY, SYRACUSE	8801	0.005	13.3	0.2	0.07	0.0010	144	164	170	185	219	240	189	41	49.2	-53
28	SICILY, SYRACUSE	8801	0.005	12.7	0.2	0.08	0.0007	143	164	170	185	222	244	190	42	49.3	-49
142	SICILY, SYRACUSE	8802	0.005	13.5	0.2	0.08	NEG	149	168	175	191	226	246	195	41	48.9	-50
103	SICILY, SYRACUSE	8803	0.005	11.2	0.2	0.07	NEG	150	166	171	185	218	241	190	41	48.7	-49
145	SICILY, SYRACUSE	8804	0.005	11.2	0.3	0.05	NEG	142	164	168	184	218	240	189	38	49.2	-52
146	SICILY, SYRACUSE	8805	0.005	12.2	0.3	0.05	0.0005	139	165	171	185	219	239	190	41	48.9	-53
108	SICILY, SYRACUSE	8806	0.005	10.9	0.3	0.04	NEG	143	164	171	186	221	241	190	42	48.7	-51
128	SICILY, SYRACUSE	8808	0.005	11.0	0.2	0.04	NEG	150	170	176	191	226	251	196	42	48.4	-51
119	SICILY, SYRACUSE	8808	0.005	11.6	0.2	0.03	NEG	146	163	172	187	221	239	190	41	48.9	-50
137	SICILY, SYRACUSE	8809	0.007	10.6	0.3	0.06	NEG	143	163	168	182	217	239	187	41	49.9	-52
131	SICILY, SYRACUSE	8809	0.005	10.6	0.3	0.09	NEG	146	165	171	186	220	241	190	41	49.3	-51
158	SICILY, SYRACUSE	8810	0.006	12.4	0.2	0.09	NEG	148	167	173	189	225	242	194	41	48.4	-54
169	SICILY, SYRACUSE	8810	0.005	11.6	0.3	0.08	NEG	142	163	169	185	220	240	189	41	48.7	-51
179	SICILY, SYRACUSE	8810	0.005	11.6	0.3	0.08	NEG	142	163	169	185	220	240	189	41	48.7	-51
172	SICILY, SYRACUSE	8811	0.005	13.2	0.1	0.07	0.0007	144	167	172	188	220	240	192	40	49.3	-50
180	SICILY, SYRACUSE	8811	0.005	11.5	0.1	0.04	0.0006	147	168	175	191	225	250	195	41	49.3	-48
181	SICILY, SYRACUSE	8811	0.005	13.2	0.1	0.07	0.0007	144	166	172	188	221	243	192	41	48.9	-50
190	SILICY, SYRACUSE	8811	0.005	11.5	0.1	0.04	0.0006	147	168	175	191	225	250	195	41	49.3	-48
	SICILY, AVERAGES		0.005	11.9	0.2	0.06	0.0003	144	165	171	186	221	242	191	40.9	49.0	-51
141	SPAIN, CADIZ	8809	0.003	21.6	0.5	0.01	0.0003	183	196	200	213	240	260	216	59	41.5	-60
163	SPAIN, HUELVA	8810	0.002	16.5	0.4	0.12	0.0010	144	169	176	198	245	259	204	42	42.8	-48
186	SPAIN, HUELVA	8812	0.003	17.1	0.4	0.13	0.0008	143	167	172	193	243	267	201	42	44.5	-49
175	SPAIN, MADRID	8811	0.003	16.4	0.1	0.07	0.0005	153	171	178	199	240	260	203	45	44.4	-48
	SPAIN, AVERAGES		0.003	17.9	0.4	0.08	0.0007	155	175	181	200	242	261	206	47.0	43.3	-51
29	VENEZUELA, LAGOVEN	8803	0.012	18.8	2.5	0.12	0.0005	163	179	188	204	242	263	208	51	41.9	-55
104	VENEZUELA, LAGOVEN	8806	0.007	18.8	2.5	0.20	0.0004	167	187	193	211	250	269	216	55	41.6	-51
117	VENEZUELA, LAGOVEN	8807	0.007	18.5	3.0	0.19	0.0004	164	187	194	214	252	272	218	52	41.4	-50
	LAGOVEN AVERAGES		0.009	18.7	2.7	0.17	0.0004	164	184	191	209	248	268	214	52.7	41.6	-52
143	VENEZUELA, MARAVEN	8805	0.012	16.2	0.8	0.08	0.0003	143	164	168	189	234	260	196	42	46.3	-52
105	VENEZUELA, MARAVEN	8806	0.013	17.0	0.6	0.10	0.0004	148	167	173	194	230	262	197	44	45.6	-54
116	VENEZUELA, MARAVEN	8807	0.008	16.9		0.06	0.0004		170		201	246	268	206	44	44.3	-48
110	VENEZUELA, MARAVEN	8807	0.012	16.9	0.7	0.10	0.0004	149	170	177	200	244	270	205	46	45.1	-48
118	VENZELELA, MARAVEN	8803	0.012	17.5	0.7	0.01	0.0003	149	171	178	200	244	271	205	[illegible]	44.9	-48
	MARAVEN AVERAGES		0.011	16.9	0.7	0.07	0.0004	147	168	174	197	240	266	202	44.0	45.2	-50

GRAV API	FREEZ POINT	VISC CST -20	SMOKE PT	H2 WT %	COMB REPORT BTU/LB	(BTU/LB) D3338	EXIST GUM	WSIM	FSII %	ANTIOXIDANT CONC	ANTIOXIDANT TYPE	CORROS INHIB MG/L	CORROS INHIB TYPE	MDA MG/L	FILT TIME MIN	SOLIDS MG/L	JFTOT MM HG	JFTOT CODE
48	-53	3.3		13.93		18617	1.0										0	1
45.2	-50	3.2	26	13.84	18611	18590	3.0	92		17.2	H14733	8.9	HI 580	5.7	6	0.42	0	1
46.3	-53	3.6	26	14.06	18660	18647	2.0	82		17.2	H14733	8.6	HI 580	5.7	6	0.26	0	1
46.4	-52	3.6	26	13.94	18631	18622	2.0	78		17.2	H14733	8.9	HI 580	5.7	8	0.45	0	1
47.4	-58	2.7	27	14.05	18650	18645	2.0	78		17.2	H14733	8.9	HI 580	5.7	6	0.45	0	1
46.5	-47	3.1	25	14.31	18652	18636	2.0	90		17.2	H14733	8.9	HI 580	5.7	5	0.30	0	1
45.8	-47	3.9	26	14.28	18616	18623	2.0	88		17.2	H14733	8.6	HI 580	5.7	9	0.55	0	1
45.8	-48	3.9	26	14.34	18616	18640	2.0	84		17.2	H14733	8.6	HI 580	5.7	4	0.52	0	1
46.8	-55	4.1	26	14.32	18651	18641	2.0	97		17.2	H14733			5.7	6	0.37	0	1
48.0	-58	3.8	26	14.33	18673	18682	2.0	98		17.2	H14733			5.7	6	0.65	0	1
46.5	-52	3.5	26.0	14.16	18640	18636	2.1	87		17.2		8.8		5.7	6.2	0.44	0	1
49.2	-53	3.3	28	14.20		18682	0.0	75	0.12	20.0	A	12.0	N 5403	5.8	7	1.10	2	1
49.3	-49	3.3	28	14.23		18690	0.0	78	0.12	20.0	A	12.0	N 5403	5.8	9	0.98	2	1
48.9	-50	3.3	27	14.50		18685	0.0	72	0.13	20.0	A	12.0	N 5403	5.8	10	1.00	2	1
48.7	-49	3.3	27	14.48		18689	0.0	86	0.11	20.0	A	12.0	N 5403	5.8	9	0.71	2	1
49.2	-52	3.3	28	[illegible]		18701	0.0	70	0.12	20.0		[illegible]	N 5403	5.8	10	0.70	2	1
48.9	-53	3.3	28	[illegible]		18688	0.0	82	0.12	20.0		12.0		5.8	8	0.80	2	1
48.7	-51	3.3	28	[illegible]		18697	0.0	72	0.12	20.0	A	12.0	N 5403	5.8	9	0.47	2	1
48.4	-51	3.3	27	14.50		18701	0.0	96	0	20.0	A	12.0	N 5403	5.8	8	0.68	2	1
48.9	-50	3.3	26	14.50		18697	0.0	80	0.12	20.0	A	12.0	N 5403	5.8	10	0.60	2	1
49.9	-52	3.3	28	14.58	18744	18716	0.0	97		20.0	A				9	0.40	2	1
49.3	-51	3.3	28	14.55	18830	18705	0.0	72	0.12	20.0	A	12.0	N 5403	5.8	6	0.45	2	1
48.4	-54	3.3	26	14.47	18701	18679	0.0	88		20.0	A	12.0	N 5403	5.8	14	0.45	2	1
48.7	-51	3.3	27	14.48	18606	18684	0.0	89	0.11	20.0	A	12.0	N 5403	5.8	10	0.2	2	1
48.7	-51	3.3	27	14.48	18600	18684	0.0	89	0.11	20.0	A	12.0	N 5403	5.8	10	0.2	[illegible]	1
49.3	-50	3.3	26	14.45	18589	18690	0.0	98		20.0	A				9	0.4	2	1
49.3	-48	3.1	27	14.48	18615	18714	0.0	98		20.0	A	12.0	N 5403	5.8	8	0.69	2	1
48.9	-50	3.3	26	14.42	18589	18682	0.0	99		20.0	A				9	0.36	2	1
49.3	-48	3.1	27	14.47	18615	18714	0.0	98		20.0	A	12.0	N 5403	5.8	8	0.69	2	1
49.0	-51	3.3	27.2	14.45	18654	18694	0.0	86	0.11	20.0		12.0		5.8	9.1	0.60	2.0	1
41.5	-60	5.3	21	13.90	18529	18525	0.6	98	0.11	20.0		11.3	HI 580		8	0.80	0	0
42.8	-48	4.6	23	14.00	18550	18545	0.7	92		20.0	E 733				8	0.70	1	[illegible]
44.5	-49	4.5	24	14.37	18572	18570	0.4	94		20.0					10	0.5	1	0
44.4	-48	4.5	22	14.11	18572	18586	0.8	98		19.2					12	0.3	1	0
43.3	-51	4.7	22.5	14.09	18556	18557	0.63	96	0.11	19.8		11.3			9.5	0.58	0.8	0
41.9	-55	5.6		13.94	18516	18519	1.1	91		20.0	AO-30	13.7	HI 580		7	0.27	0	1
41.6	-51	5.1		13.59	18516	18517	1.1	95			AO-30		HI 580		7	0.34	0	1
41.4	-50	5.4		13.79	18507	18519	1.0	95		22.0	AO-30	[illegible]	HI 580		8	0.32	0	1
41.6	-52	5.4		13 78	18513	18518	1.07	94		21.0		11.2			7.3	0.31	0	1
46.3	-52	3.7	23	14.24	18630	18611	0.5	90	0.17	21.0	AO-30	13.4	HI 580		7	0.37	0	1
45.6	-54	3.8	23	13.83	18622	18590	0.4	94	0.12	22.9	AO-30	14.8	N 5403		7	0.48	0	1
44.3	-48	4.4		13.80	18574	18587	0.4				AO-30						0	1
45.1	-48	4.1	22	13.85	18595	18596	0.5	92	0.11	18.5	AO-30	12.0	N 5403		6	0.58	0	1
44.9	-48	4.2	23	14.23	18596	18601	0.4	80	0.12	22.7	AO-30	14.8	N 5403		8	0.19	0	1
45.2	-50	4.0	22.8	13.99	18603	18597	0.44	89	0.13	21.3		13.8			7.0	0.41	0	1

SII	ANTIOXIDANT CONC	ANTIOXIDANT TYPE	CORROS INHIB MG/L	CORROS INHIB TYPE	MDA MG/L	FILT TIME MIN	SOLIDS MG/L	JFTOT MM HG	JFTOT CODE	CETANE INDEX	DIST AVE F	D3338 UNCOR FOR S
								0	1		385.4	18637
	17.2	HI4733	8.9	HI 580	5.7	6	0.42	0	1	43	392.6	18606
	17.2	HI4733	8.6	HI 580	5.7	6	0.26	0	1	44	385.4	18653
	17.2	HI4733	8.9	HI 580	5.7	3	0.45	0	1	44	387.8	18630
	17.2	HI4733	8.9	HI 580	5.7	6	0.45	0	1	44	377.0	18655
	17.2	HI4733	8.9	HI 580	5.7	5	0.30	0	1	46	392.6	18644
	17.2	HI4733	8.6	HI 580	5.7	9	0.55	0	1	48	395.6	18644
	17.2	HI4733	8.6	HI 580	5.7	4	0.52	0	1	48	411.2	18661
	17.2	HI4733			5.7	6	0.37	0	1	44	381.2	18649
	17.2	HI4733			5.7	[illegible]	0.65	0	1	43	379.4	18683
	17.2		8.8		5.7	6.2	0.44	0	1	44.9		
12	20.0	A	12.0	N 5403	5.8	7	1.10	2	1	45	372.8	18692
12	20.0	A	12.0	N 5403	5.8	9	0.98	2	1	46	374.6	18702
13	20.0	A	12.0	N 5403	5.8	10	1.00	2	1	47	383.0	18697
11	20.0	A	12.0	N 5403	5.8	9	0.71	2	1	45	373.4	18699
12	20.0		12.0	N 5403	5.8	10	0.70	2	1	45	371.6	18708
12	20.0		12.0		5.8	8	0.80	2	1	45	373.4	18696
12	20.0	A	12.0	N 5403	5.8	9	0.47	2	1	45	374.6	18703
	20.0	A	12.0	N 5403	5.8	8	0.68	2	1	47	384.2	18706
12	20.0	A	12.0	N 5403	5.8	10	0.60	2	1	45	374.6	18702
	20.0	A				9	0.40	2	1	44	369.2	18725
12	20.0	A	12.0	N 5403	5.8	6	0.45	2	1	45	374.6	18718
	20.0	A	12.0	N 5403	5.8	14	0.45	2	1	44	380.6	18672
11	20.0	A	12.0	N 5403	5.8	10	0.2	2	1	45	372.8	18695
11	20.0	A	12.0	N 5403	5.8	10	0.2	2	1	45	372.8	18695
	20.0	A				9	0.4	2	1	44	377.0	18700
	20.0	A	12.0	N 5403	5.3	8	0.69	2	1	50	382.4	18720
	20.0	A				9	0.36	2	1	44	377.0	18692
	20.0	A	12.0	N 5403	5.8	8	0.69	2	1	50	382.4	18720
11	20.0		12.0		5.8	9.1	0.60	2.0	1	45.6		
11	20.0		11.3	HI 580		8	0.80	0	0	40	421.4	18527
	20.0	E 753				8	0.70	1	1	40	399.2	18562
	20.0					10	0.5	1	0	39	393.8	18588
	19.2					12	0.3	1	0	40	398.0	18596
11	19.8		11.3			9.5	0.58	0.8	0	39.8		
	20.0	AO-30	13.7	HI 580		7	0.27	0	1	38	407.0	18536
		AO-30		HI 580		7	0.34	0	1	41	420.8	18545
	22.0	AO-30	8.6	HI 580		8	0.32	0	1	42	423.8	18546
	21.0		11.2			7.3	0.31	0	1	40.3		
7	21.0	AO-30	13.4	HI 580		7	0.37	0	1	42	384.2	18522
2	22.9	AO-30	14.8	N 5403		7	0.48	0	1	43	386.6	18604
		AO-30						0	1		402.2	18595
1	18.5	AO-30	12.0	N 5403		6	0.58	0	1	44	400.4	18611
2	22.7	AO-30	14.8	N 5403		5	0.19	0	1	43	401.0	18603
3	21.3		13.6			7.0	0.41	0	1	43.0		

TABLE 2. F-34 SHIPMENTS DURING 1988

SOURCE	BARRELS	FRACTION OF TOTAL	DESTINATIONS
BAHRAIN	23,600	0.003067	POHUNG
GELSENKIRCHEN, GERMANY	296,900	0.038584	GERMANY
KARLSRUHE, GERMANY	58,000	0.007537	GERMANY
WORTH, GERMANY	512,800	0.066642	GERMANY
ST THEODORE, GREECE	1,709,100	0.222108	UK, FRANCE
PRIOLO SYRACUSA, SICILY	3,082,400	0.400577	AZORES, ITALY, SPAIN, UK
SPAIN (3 REFINERIES)	596,000	0.077454	UK, FRANCE
LAGOVEN, VENEZUELA	350,500	0.045563	UK, FRANCE
MARAVEN, VENEZUELA	1,065,500	0.138468	AZORES, GREENLAND, SPAIN, US
TOTAL, BBLS	7,69[illegible],900	1.000000	

NOTE: US F-34 REQUIREMENTS FOR EUROPE ESTIMATED

TO BE 13,900,000 BBL FOR JULY 88 TO JUN 89

3

NALCO 5403 are used. The antioxidants used were MTBX55, Kero TP, 2,6-di-tert-butyl-4-methylphenol, Hitec 4733, Ethyl 733, and DuPont AO-30.

3. Fuel Shipment Modes and Destinations

Table 2 shows the sources and destinations of the fuels. The refinery in Gelsenkirchen, Germany, shipped all of its fuel via barge to the DFSC terminal at Speyer, Germany. The refinery in Karlsruhe, Germany, also delivered via barge to the DFSC terminal at Karlsruhe, Germany. The refinery in Worth, Germany, delivered fuel to the CEPS pipeline at Worth, Germany. The refinery in Bahrain (Persian Gulf) delivered its one shipment via tanker to Pohang, Korea. The refinery in St Theodore, Greece, delivered fuel via tanker to the CEPS at Donges, France, and to the United Kingdom. Note that the shipments from Greece to the CEPS included corrosion inhibitor additive, but the shipments to the UK did not.

The refinery at Priolo Syracusa, Sicily, delivered fuel by tanker to the Azores, Italy, Spain, and the United Kingdom. Three separate refineries in Spain delivered fuel to the United Kingdom, to France, and to one undetermined destination. The two refineries in Venezuela delivered fuel to the CEPS at Donges, France, to the United Kingdom, to the Azores, to Spain, and one load to the United States.

When comparing Tables 1 and 2, note that the individual fuel shipments from Gelsenkirchen, Karlsruhe, and Worth, Germany, were quite small (about 10,000 to 20,000 barrels each), as compared to individual fuel shipments from Greece, Sicily, Spain, and Venezuela (55,000 to 236,000 barrels each.) This resulted in 29 fuel reports for Gelsenkirchen, Germany, and only three for Lagoven, Venezuela; yet more fuel was shipped from Lagoven than from Gelsenkirchen. Thus, the fractions of the total F-34 fuel shipped were used to calculate the weighted averages of properties found in Table 3.

As different batches of fuel were intended for different destinations, their additive contents were varied accordingly. For example, fuels intended for the UK pipeline are normally procured without corrosion inhibitor/lubricity improver additive and without the fuel system icing inhibitor. This is because these fuels will be clay-filtered prior to delivery to the DFSC terminals, and clay tends to remove these additives. (These additives will be injected by the DFSC prior to delivery to USAF bases.) Other fuel batches were delivered with all mandatory and some optional additives present. Thus, the fuels included in this report include both F-34 and F-35.

TABLE 3. AVERAGES OF F-34 PROPERTIES

PROPERTY	BAHRAIN	GERMANY			GREECE	SICILY	SPAIN	VENEZUELA		AVERAGE	WEIGHTED
		GELSEN.	KARLSRUHE	WORTH				LAGOVEN	MARAVEN		AVERAGE*
ACID NO.	0.001	0.004	0.008	0.010	0.004	0.005	0.003	0.009	0.011	0.006	0.006
AROMATICS %	19.2	13.1	16.3	17.5	14.0	11.9	17.9	18.7	17.5	16.2	14.50
OLEFINS %		0.3	0.6	0.5	0.3	0.2	0.4	2.7	0.7	0.71	0.63
SULFUR, TOTAL	0.14	0.01	0.05	0.01	0.08	0.06	0.08	0.17	0.07	0.07	0.08
SULFUR, MERCAP.	0.0008	0.0010	0.0005	0.0001	0.0008	0.0003	0.0007	0.0004	0.0004	0.0006	0.0005
DISTILL, AVG	196	202	199	189	198	191	206	214	202	200	198
FLASH POINT	40	53	46	47	43	41	47	53	44	46	45
API GRAVITY	48.0	43.3	46.2	44.7	46.5	49.0	43.3	41.6	45.2	45.3	46.3
FREEZE POINT	-53	-60	-53	-60	-52	-51	-51	-52	-50	-53	-52
VISCOSITY	3.3	4.5	4.0	3.4	3.5	3.3	4.7	5.4	4.0	4.0	3.8
SMOKE POINT		24.3	24.0	25.2	26.0	27.2	22.5		22.8	24.6	23.3
HYDROGEN WT %	13.93	14.04	13.97	13.98	14.76	14.45	14.09	13.78	13.99	14.04	14.19
BTU/LB	18617	18600	18620	18563	18636	18694	18557	18518	18597	18600	18629
EXISTENT GUM	1.00	0.30	0.80	1.00	2.10	0.00	0.63	1.07	0.44	0.82	0.77

*BASED ON FRACTION OF TOTAL PRODUCT SUPPLIED (SEE TABLE 2)

SECTION III - DISCUSSION

1. Discussion of Reported Properties.

Each of the properties or measurements listed in Table 1 are discussed below. Although Table 1 includes both F-34 and F-35 fuels, they are combined in Tables 1, 2, and 3 and are referred to as F-34, except where noted. Table 3 lists the averages of selected fuel properties by source (i.e., source average). Table 3 also lists the averages of these properties from all sources, using two methods: (a) the simple average of the source averages, and (b) the weighted average where each source average is multiplied by the fraction of the total F-34 obtained from that source. For the discussion of properties, below, the source averages and the total weighted averages are used.

A. Acid Number - The acid number limits the amount of acidic components in the fuel. These acidic components might be carried over from the crude oil, formed or added in refinery processes, or added unintentionally. The specification level is 0.015 mg KOH/gm fuel. None of the fuels exceeded the specification limit. However, the average acid number varied by an order of magnitude among sources, with the Worth, Germany refinery and the two Venezuela refineries having relatively high acid numbers. The average was 0.006 mg KOH/gm fuel.

B. Aromatics Content - Aromatics are unsaturated, cyclic hydrocarbons that are excellent solvents, have a strong odor (hence the name aromatics), but have poor combustion performance. Due to the effect of aromatics on combustion and on the swell characteristics of elastomers, MIL-T-83133 limits the aromatics content to 25 percent by volume. None of the fuels exceeded or even approached this limit. The average aromatics content was only 14.5 percent by volume. The variation in aromatics content by source, as seen in Table 3, may be due to the types of crude oil processed or to the particular refinery processes used.

C. Olefins Content - Olefins are chain and branched chain paraffinic hydrocarbons that have double carbon bonds. The double carbon bonds reduce molecular stability, which can lead to the formation of gums during storage. Although the olefins are limited to 5 percent by volume, the average olefins content was only 0.6 volume percent. The Lagoven, Venezuela, F-34 reported the highest olefins content at 2.7 volume percent.

D. Sulfur Content - Sulfur is limited in jet fuels because of its corrosive action and noxious combustion products. The F-34 had an average sulfur content of 0.08 weight percent, well below the specification limit of 0.30 weight percent. Comparing the total sulfur in F-34 by source, the fuels produced in Bahrain and Lagoven, Venezuela had significantly higher sulfur contents than the fuels produced elsewhere.

E. Mercaptan Sulfur Content - Mercaptan sulfur is one of the most noxious forms of sulfur, both in odor and in corrosiveness. The average mercaptan sulfur content was only 0.0005 weight percent. None of the fuels exceeded 0.001 weight percent, even though the Specification MIL-T-83133B allows up to 0.002 weight percent. Commercial Jet A-1 specifications, including the ASTM D 1655 and the Joint Fueling Systems Check List, allow up to 0.003 weight percent mercaptan sulfur. As all F-34 suppliers easily met the 0.002 weight percent limit, the specification limit of 0.002 weight percent appears to be reasonable.

The USAF requires a low mercaptan sulfur limit because 120 of its oldest KC-135 aircraft use an obsolete fuel tank sealant. This sealant is degraded by mercaptan sulfur concentrations greater than 0.002 weight percent[3].

F. Distillation Range - None of the F-34 fuels approached the maximum allowable 10 percent recovered temperature of 205°C or the maximum allowable end point temperature of 300°C. The source average distillation temperature (average of the 10%, 50%, and 90% temperatures) varied from 191° to 214°C (see Table 3).

G. Flash Point - All fuels met or exceeded the minimum allowable flash point of 38°C. The average flash point was 45°C.

H. Gravity - The allowable API gravity range is 37 to 51° API. The F-34 fuels had API gravities ranging from 41.4 to 49.9 with an average of 46.3. This is equivalent to a density of 0.7958 kg/L (6.626 lbs/gallon).

I. Freezing Point - All fuels met the specification limit of -47° C. The weighted average freezing point was -52°C or lower, as many of the fuel reports gave a "less than" freezing point.

J. Viscosity - The viscosity of jet fuels is critical to engine starting and relight, as starting performance requires excellent fuel atomization, and atomization is a function of viscosity. The specification limit is 8.0 centistokes at -20°C. The F-34 fuels had an average viscosity of 3.8 centistokes with a

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3 Miller, L. O., Effects of Mercaptan Compounds in JP-4 on Rubber Materials at High Temperatures, WADC-TN-56-347, June 1956.

maximum reported value of only 5.6 centistokes. Thus, good engine starting and altitude relight performance would be expected with all of the F-34 fuels reported.

K. Smoke Point - The smoke point test method measures the maximum flame height that can be obtained without smoking, using a special wick lamp. Smoke point correlates with fuel combustion performance in gas turbine engines. A high smoke point insures that the fuel will burn with a minimum of exhaust smoke. The F-34 fuels reported an average smoke point of 23.3 mm. The minimum reported smoke point was only 21 mm, well above the minimum allowable limit of 19 mm. The high smoke points are in agreement with the low aromatics content reported above, as high aromatics content fuels tend to have low smoke points.

L. Hydrogen Content - The hydrogen content of jet fuels also correlates with fuel combustion performance. The hydrogen content was calculated for all fuels of Table 1 using ASTM D 3343. The average hydrogen content was 14.19 percent by mass, well above the minimum allowable hydrogen content of 13.4 percent.

M. Heat of Combustion - The heat of combustion reported in Table I includes calorimeter data, aniline-gravity correlations of ASTM D 1405, and estimation methods using ASTM D 3338. To provide a standard method for comparison, the heat of combustion for each fuel was calculated using ASTM D 3338. All F-34 fuels exceeded the minimum specification limit of 18,400 Btu/lb. The average heat of combustion was 18,629 Btu/lb.

M. Thermal Oxidative Stability - Jet fuel is used as a coolant for airframe and engine components, so the fuel must be able to withstand elevated temperatures without forming deposits within the fuel system and fuel components. The Jet Fuel Thermal Oxidative Tester (JFTOT) apparatus is used to insure that the fuel has acceptable thermal stability. The JFTOT detects the formation of deposits on a polished aluminum heated tube and changes in pressure drop across a filter located downstream of the heated tube. Any deposit formed on the heated tube must be less than a light tan (visual deposit code of 3), and the maximum pressure drop across the filter must be less than 25 mm of mercury. As seen in Table 1, all F-34 fuels easily passed the JFTOT.

N. Existent Gum - Jet fuels are good solvents and may contain high molecular weight gums and resins dissolved therein. These gums and resins may form deposits within the fuel system and combustor with changes in fuel temperature and with the evaporation of the fuel within the combustor. To measure the existent gum, a sample of the fuel is evaporated and the amount of deposit remaining is weighed. The existent gum content of all

F-34 fuels was well below the specification limit of 7 mg/100 mL. The average value was only 0.77 mg/100 mL. The fuels from Greece had almost three times the weighted average value.

O. Particulate Matter - This test measures the quantity of solid particulates (contaminants) in the fuel. One gallon of fuel is filtered through a 0.8-micron pore size membrane filter. The weight gain of the filter (after drying) is reported as solid particulates. This test is a measure of the cleanliness of the fuel upon delivery to the Defense Fuels Supply Center. Five of the fuels exceeded the specification limit of 1.0 mg/L.

P. Filtration Time - MIL-T-83133 (F-34 & F-35) and MIL-T-5624 (F-40 and F-44) specifications limit the time required to filter a one gallon sample of fuel through a 0.8-micron membrane filter. (This test may be run in conjunction with the Particulate Matter test, above). The purpose of this test is to insure that the fuel does not contain contaminants that will rapidly plug filter-water separators used at USAF bases to insure that only clean, dry fuel is serviced to aircraft. The source of the contaminants may be free water, solid particulates (sand, rust, fibers, metal chips, etc..), and traces of refinery treating solutions. In addition, MIL-I-25017 fuel corrosion inhibitor/lubricity improver additives may react with water-soluble metals to form gelatinous soap-like materials. Although the mass of this gelatinous material may be below the Particulate Matter limits, above, the material can rapidly plug filters. Compliance with the Filtration Time test has greatly reduced filter replacement requirements at AF bases and the chance of servicing contaminated fuel to aircraft. None of the fuels exceeded the 15-minute filtration time allowed by MIL-T-83133. However, several fuels were reported to take exactly 15 minutes. The fuels obtained from Gelsenkirchen, Germany, and Sicily tended to have relatively high filtration times.

Q. Water Separation Index - The most common and potentially serious contaminant in jet fuel is water. At USAF bases, filter-separators are used to remove Particulate Matter and undissolved water from the fuel at least twice between receipt and prior to aircraft servicing. Filter-separators remove solid contaminants by depth filtration. Undissolved water is removed through coalescence of small droplets into large droplets. The water droplets are then separated by gravity and by a hydrophobic filter. Coalescence of water can be degraded or prevented by trace quantities of surface active materials (surfactants) in the fuel. Surfactants can also degrade the performance of depth filtration by preventing the agglomeration of many small particles into larger, easily filtered particles.

The Water Separometer is a miniature coalescence test device in which a small quantity of water is emulsified in the fuel sample. The ability of the coalescer to remove the water is then determined. A Water Separation Index Modified (WSIM) rating of 100 is excellent; a rating of less than 70 is cause for concern. As fuel additives affect the WSIM, different limits are placed on the fuel, depending on which additives are present. An average WSIM value of 92 was calculated from Table 1 data. This relatively high value indicates that the fuels were essentially free of surfactants.

2. Interpretation of Results

A. Low Temperature Performance

(1) Engine Starting and Relight - With the conversion to F-34 from the less viscous, more volatile F-40, the cold starting and altitude relight performance of USAF aircraft becomes of concern. Most aviation turbine engine companies state that their engines will start and operate satisfactorily with fuels that have a viscosity of 12 centistokes or less. Table 4, below, lists the viscosity of the average F-34 and the maximum viscosity F-34. Also listed are the estimated fuel temperatures at which the viscosity of the fuel will equal 12 centistokes.

TABLE 4. VISCOSITIES OF F-34

JP-8 Fuel	Visc at -20°C	Temp at 12 cSt
Average	3.8	-50°C
Maximum	5.6	-39°C
Specification Limit	8.0	-29°C

A review of Table 4 indicates that engine starting (i.e., 12 centistokes) should not be a problem with the average F-34 down to below its maximum allowable freezing point of -47°C. The worst fuel should still allow starting down to -39°C.

(2) Fuel Freezing During Flight - For long duration, high altitude flights and for operation in cold climates, the freezing point of fuel is also critical. The fuel must not be allowed to freeze within the fuel tanks, as this could prevent fuel flow to the engine. The maximum allowable freezing point of -47°C for F-34 fuel was selected to insure that USAF flight operations will not be compromised by the freezing point of the fuel, except possibly for operations from a few arctic bases during unusually cold weather. Commercial US airlines use Jet A

(freezing point of $-40^{o}C$) for transcontinental and many transoceanic flights, but many foreign commercial airlines use F-35 (Jet A-1) for all flights.

B. Fuel Energy Content - Aircraft may be either weight limited or volume limited; i.e., the fuel load and cargo or bomb load may be constrained by the maximum allowable gross weight at take-off or by the available space for cargo or weapons. Weight-limited aircraft can increase their range when using a fuel that maximizes energy content per unit mass. Conversely, volume-limited aircraft obtain increased range when using a fuel that maximizes energy content per unit volume. Table 5 shows that, compared to F-40, F-34 has about 0.38 percent less energy content per unit mass and about 4.0 percent more energy content per unit volume. Thus, with F-34 there is less than one-half percent range penalty for weight-limited aircraft but about a three to four percent increase in range for volume-limited aircraft.

TABLE 5. ENERGY CONTENT OF FUELS

Fuel	Btu/Lb	Btu/Gallon
Avg F-40	18,700	118.700
Avg. F-34	18,629	123,436

C. Correlation of Properties - High average distillation temperatures would be expected to be reflected in lower API gravities (i.e., higher density) and higher viscosities. Figure 1 is a plot of the Table 3 source averages for API gravity data versus the average distillation temperatures. As is evident, there is a definite trend as anticipated. Figure 2 is a plot of viscosity versus average distillation temperature. As expected, there is also a good correlation evident for these two properties. A good correlation is also evident for viscosity and API gravity, as seen in Figure 3.

Aromatics are more dense than paraffins and cycloparaffins (naphthenes), the other major constituents of jet fuels. Figure 4 is a plot of aromatics content versus API gravity. Except for fuels from Gelsenkirchen, Germany, an excellent correlation is evident. The reasons for this anomaly are not apparent, but a high cycloparaffin content could account for the lower API gravity of the Gelsenkirchen fuels.

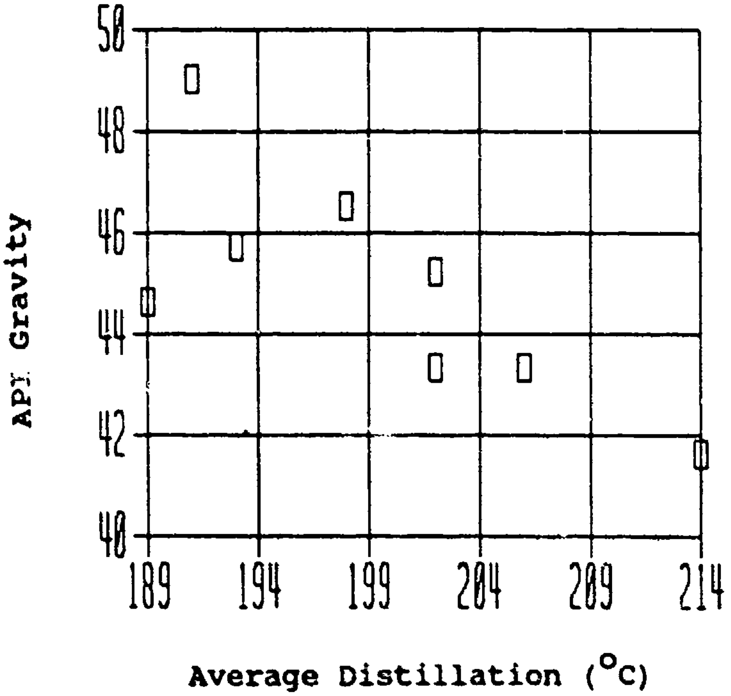

Figure 1. API Gravity Vs. Average Distillation Temperature

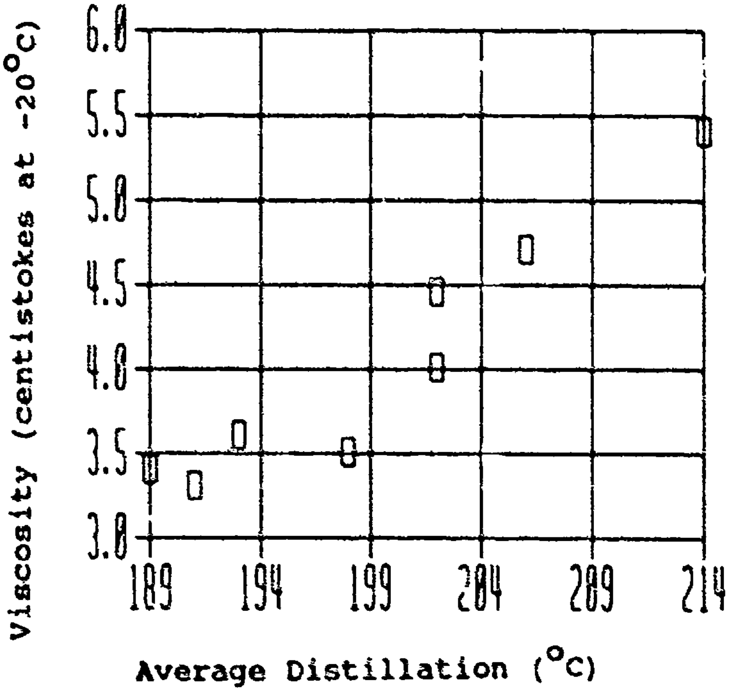

Figure 2. Viscosity Vs Average Distillation Temperature

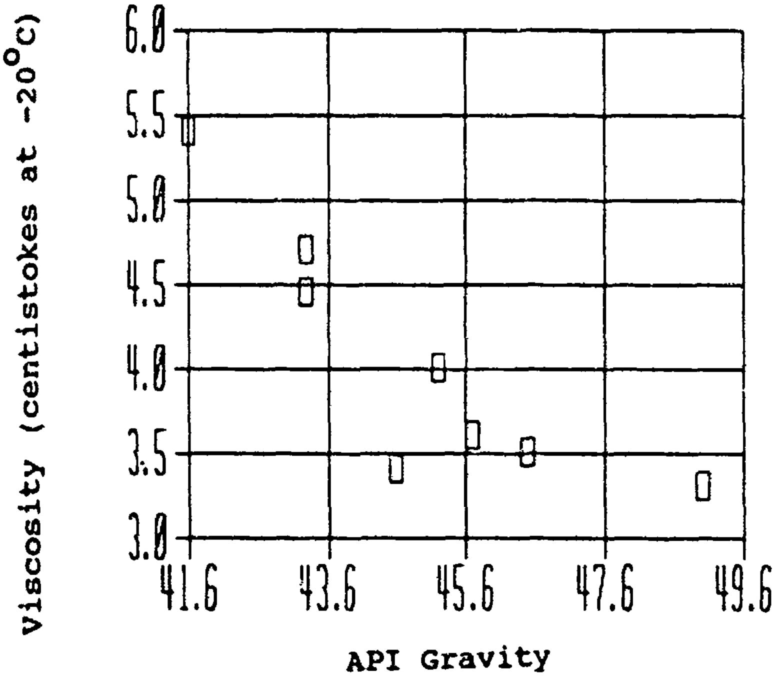

Figure 3. Viscosity Vs API Gravity

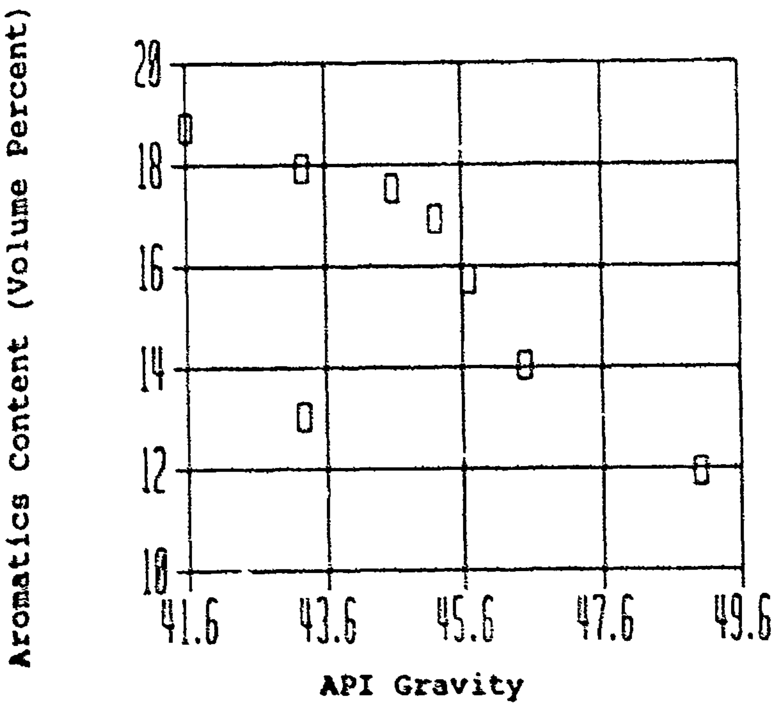

Figure 4. Aromatics Content Vs. API Gravity

D. Cetane Index - The US Army has requested that the Cetane Index for all F-34, F-35, and F-44 fuels be reported. These fuels may be used in ground or shipboard diesel engines. If F-34 becomes NATO's "single fuel for the battlefield", as proposed, it will become the standard diesel fuel.

The Cetane Index is calculated from the API Gravity (or density) and mid-boiling distillation temperature (50% evaporated temperature using ASTM D 86.) As seen in Table 1, most F-34 fuels have Cetane Indices above 40, and they should perform adequately in most diesel engines. However, the F-34 fuels from Worth, Germany, have Cetane indices ranging from 32 to 40 with an average of only 34. The Worth fuels have the lowest average 50% evaporated temperature (180°C) of any F-34 source and also have a lower than average API gravity. The combination of low API gravity and low mid-point distillation temperature accounts for these unusually low Cetane numbers. Figure 1 shows that the Worth fuel appears to be an outlier, with a lower than average API gravity of 44.7 and an average distillation temperature of 189°C, the lowest of any fuel.

SECTION IV - CONCLUSIONS

1. For the JP-8 fuels supplied to the Air Force for European operations in 1988, all fuel specification limits were met with room to spare. This implies that a considerable increase in the production of F-34 should be possible if the fuel properties were extended closer to specification limits.

2. A small but significant range increase can be expected for volume-limited aircraft (such as fighters) when using JP-8, as compared to JP-4.

SECTION V - RECOMMENDATIONS

1. The F-34 properties should be surveyed periodically to determine if there are any significant changes in properties that might affect flight operations.

2. When the conversion to F-34 in the western Pacific is completed, a F-34 survey of those fuels should be made.

3. Future pipelines for aviation turbine fuels should follow the design of the UK pipeline. The UK pipeline allows the transfer of uninhibited F-34 (i.e., F-35) with clay filtration prior to the delivery of the fuel to DFSC terminals. (The F-35 is converted to F-34 at the terminals.) This approach has greatly improved the purity of fuel delivered to USAF bases, reducing ground filter element replacement and the chance of servicing contaminated fuel to aircraft.

4. All F-34/F-35 shipped by ocean-going barge or tanker should be shipped sans the corrosion inhibitor/lubricity improver (CILI) and the fuel system icing inhibitor (FSII) additives. If water contacts the fuel, the CILI additive may react with dissolved metals in the water to form a filter-plugging precipitate. Also, the FSII will migrate to any undissolved water present, creating both an environmental problem and the need to replenish the additive in the fuel.